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Abdominal Muscle Activity While Performing Trunk-Flexion Exercises Using the Ab Roller, ABslide, FitBall, and Conventionally Performed Trunk Curls

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Objective: To compare the surface electromyographic activity of the abdominal musculature and rectus femoris (RF) muscle during trunk-flexion exercises using 3 abdominal exercise devices (Ab Roller, ABslide, and FitBall) and the traditional trunk curl.

Design and Setting: Each subject performed approximately 15 repetitions for each exercise condition. A repeated-measures, one-way multivariate analysis of variance was used to compare the mean integrated electric activity value for each muscle during each exercise condition.

Subjects: A total of 10 male and 13 female collegiate undergraduate students.

Measurements: Surface electromyographic activity was recorded for the upper rectus abdominis (URA), lower rectus abdominis (LRA), external oblique (EO), and RF during 5 consecutive repetitions of each exercise bout. The signal was amplified by a factor of 1000, rectified, and integrated. These integrated values were then divided by the time value for each exercise to give the mean integrated electromyography value.

Results: A significant difference existed among exercise conditions for the RF ($P < .0001$), with the ABslide and the FitBall having greater electric activity than the other exercise conditions. Activity was significantly different ($P < .0009$) for the URA, with the ABslide having the least electric activity. For the EO, exercising with the ABslide produced significantly greater electric activity ($P < .0001$) than all other exercise conditions. No significant difference was found across exercise conditions for the LRA ($P < .051$).

Conclusions: Performing abdominal exercises with the Ab Roller, ABslide, and FitBall did not elicit greater activity of the URA and LRA than performing traditional trunk curls. Use of the ABslide elicited greater EO activity and significantly less URA activity than the other 3 modes. Both the ABslide and FitBall resulted in greater involvement of the hip flexors, an undesirable feature of abdominal exercises.

Key Words: electromyography, fitness, rehabilitation, sit-ups, abdominal crunches

Exercise and sport scientists and sports medicine professionals have long recognized that endurance of the abdominal musculature is an essential component of fitness for health and sports performance. A minimal amount of abdominal endurance is necessary for maintaining proper alignment of the axial skeleton and supporting movements of both the lower and upper extremities in activities of daily living, work, and athletic performance. Specifically, the correct alignment required to stabilize and accommodate movements of the pelvic girdle depends on adequate strength and endurance of the abdominal musculature.[1,2]

The general public is interested in the abdominal musculature not only for its relationship to back pain and proper alignment but also for the role it plays in body image. Because our society deals with obesity and inactivity, the abdominal muscles have been thrust into the spotlight. Traditionally, people have performed abdominal exercises such as sit-ups and abdominal crunches (also known as trunk curls) without the assistance of any equipment.

This heightened interest in abdominal muscle development has resulted in an explosion of abdominal exercise devices in recent years. The first type of abdominal exercise devices enabled a person to perform a controlled sit-up. They offered no resistance but allowed one to perform the sit-up motion correctly and consistently with ease. They also provided a headrest to prevent neck strains. Some of the most common names for these devices are the Ab Roller (Fitness Innovations and Technologies, Inc, North Logan, UT), AB Shaper (Icon, Logan, UT), and AB Trainer (Precise Exercise, Inc, Hillsdale, NJ).

A second type of commonly used abdominal exercise device is an exercise ball such as the FitBall (Ball Dynamics Intl, Longmont, CO), which has been available for more than a decade and is commonly used by athletic trainers and other sports medicine professionals. This ball is now being used more frequently in personal fitness programs for the general public. Even though exercise balls are becoming more commonly used, little scientific evidence is available regarding their efficacy.

The newest type of abdominal exercise equipment to appear on the market requires the athlete to roll out a wheel-like device while moving from a kneeling position into a prone layout position, then return to the kneeling position. The roll-out movement phase involves shoulder flexion and hip extension as well as lumbar spinal extension against the resistance provided by the weight of the body. Some of these devices may provide an assistive force during the return phase to lower the difficulty. Various names have been used for these devices, including ABslide (Sylmark, Inc, Los Angeles, CA) and Torso Tiger (Infotopia Inc, Canfield, OH). No investigators have evaluated the efficacy of these devices or the validity of the manufacturers' claims to promote increased endurance of the abdominal muscles. Research evaluating the effects of exercising with each of these types of abdominal exercise devices and in comparison with traditional abdominal crunches would enable sports medicine professionals, especially athletic trainers, to make appropriate decisions regarding their use in preventive and treatment protocols.

Surface electromyography (SEMG) affords an easy and effective method for assessing the level of muscle contraction,[3–12] providing both the timing and degree of muscle excitation. Previous researchers assessing the effects of variations in abdominal exercise procedures using SEMG have usually examined the 3 superficial muscles most involved in lumbar spinal flexion: upper rectus abdominis (URA), lower rectus abdominis (LRA), and external oblique (EO).[9,13,14] Exercises designed to develop the abdominal musculature should involve minimal contributions of the hip flexors.[3] The rectus femoris (RF) is therefore often monitored to provide an indicator of hip-flexor activity because it is the only superficial muscle of the hip-flexor group.

Although recent authors[12,14] have used SEMG to examine the relative effects of traditional trunk curls and abdominal exercise equipment, none have included exercises using an exercise ball or a roll-out wheel device. We compared the SEMG of the abdominal musculature (URA, LRA, EO) and RF during trunk-flexion exercises using the traditional trunk curl and 3 abdominal exercise devices (Ab Roller, ABslide, and FitBall). These devices were chosen to represent each of the 3 general types of abdominal exercise devices.

METHODS

Subjects

Ten male (age = 23.4 ± 3.9 years, height = 182.2 ± 4.2 cm, mass = 78.8 ± 6.1 kg) and 13 female (age = 20.8 ± 2.6 years, height = 166.0 ± 5.4 cm, mass = 61.6 ± 8.6 kg) collegiate undergraduates were recruited and volunteered to participate in this study. Subjects were moderately active and healthy with no back pain at the time of data acquisition. Potential subjects with more than 2.54 cm of fat at the iliac fold were eliminated before participation. Before data collection, each subject attended a mandatory orientation meeting to become familiar with the equipment, exercise technique, and protocol. All subjects provided written informed consent in accordance with the university's institutional review board, which also approved the study.

Exercise Equipment and Performance

Each subject performed 10 to 15 repetitions using each of the 3 exercise devices and the trunk curl. For the basic abdominal crunch, feet were placed flat on the ground with the knees flexed to 90°. Subjects elevated the trunk by lifting the head and shoulders such that the scapulae were lifted above the ground. We developed a device with a bar that could be positioned to the chest at the point when the scapulae came off the ground (Figure 1). This was to ensure that both scapulae were consistently elevated above the floor for each repetition. The subject was required to touch the bar on the device with each sit-up. The Ab Roller (Figure 2) allows the subject to perform a controlled trunk curl, or abdominal crunch. It offers no resistance but allows the trunk-curl motion to be done correctly and easily. The FitBall (Figure 3) is a 36-inch (91.44-cm) diameter ball that has been used in rehabilitation for at least the past decade. Its use has recently expanded into the general fitness population. The ABslide (Figure 4) is one of the most recent abdominal exercise devices to appear on the exercise-equipment market. The body position and movements involved in the use of this device are unlike the others. The athlete assumes a kneeling position and grasps the 2 handles of the ABslide, a device approximately 12 × 12 × 12 inches (30.48 cm) with 2 wheels on the bottom. The ABslide is then pushed out in front of the body, extending the knees and hips while flexing the shoulders as the body moves into a prone layout position. An internal torsion spring attached to the wheels is loaded during the roll-out movement. The elastic energy released during the return movement assists in overcoming the resistance provided by the weight of the body. The

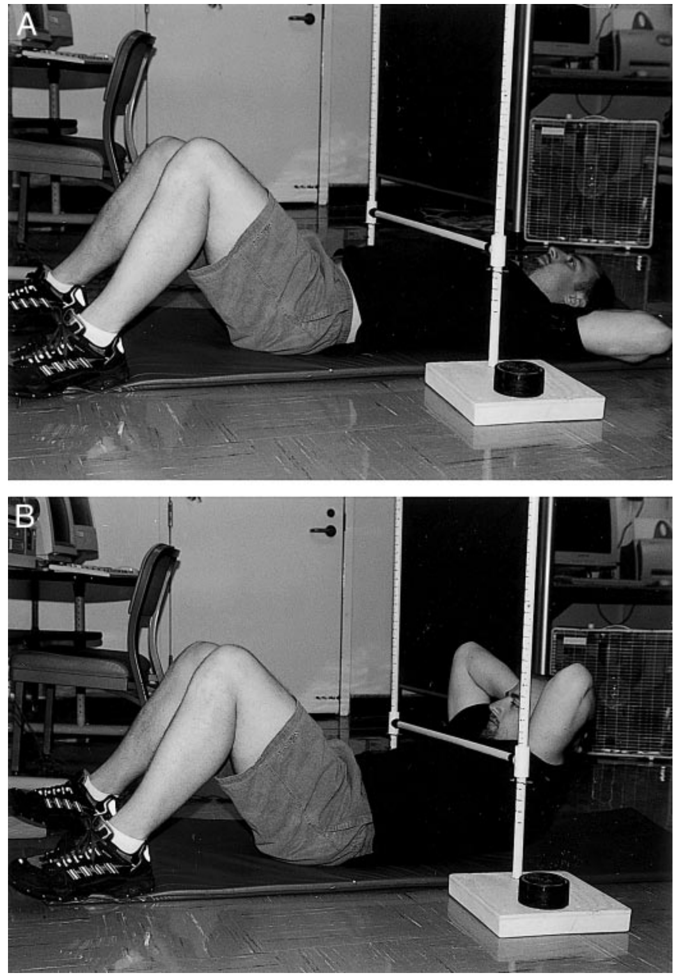

Figure 1. Traditional trunk curl. A, Start position. B, Top position.

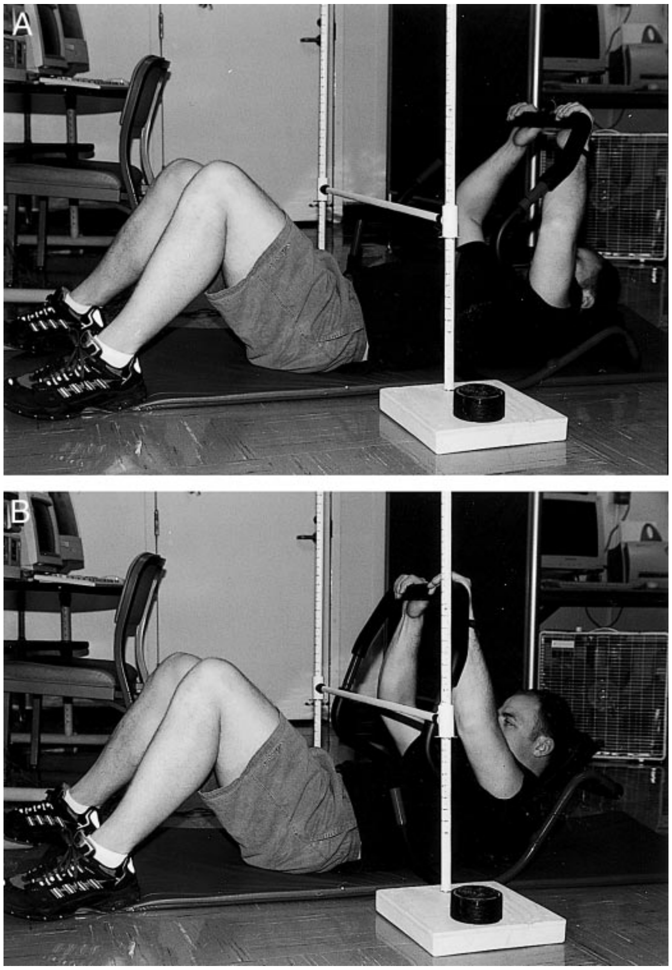

Figure 2. Ab Roller. A, Start position. B, Top position.

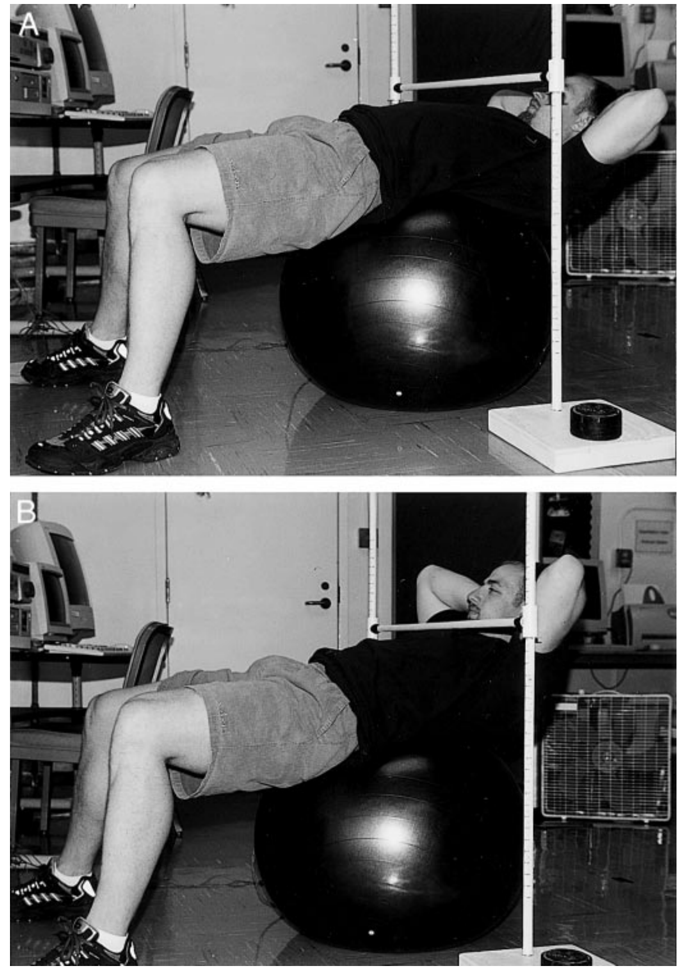

Figure 3. FitBall. A, Start position. B, Top position.

return movement involves shoulder extension and hip flexion as well as lumbar spinal flexion. Each exercise bout on each of the exercise devices was performed to the manufacturer's specifications. To ensure consistency of exercise tempo, each repetition was performed to the beat of a metronome set to 63 beats/minute, or approximately 31 repetitions per minute for the Ab Roller, FitBall, and trunk curl.

All 4 exercises were performed in 1 testing session with the order randomized using a balanced Latin square to control for order effect. A rest period of approximately 2 minutes was allowed between exercise conditions to avoid fatigue. Each trial began with the subject performing trunk curls until a consistent tempo was achieved. The computer was then activated until data were collected for 5 complete repetitions. The SEMG activity was evaluated for portions of the URA, LRA, EO, and RF muscles.

Data Acquisition

We used the Ariel Performance Analysis System (Ariel Dynamics, Inc, Trabuco Canyon, CA) to acquire and analyze the SEMG, with preamplified Motion Control (IOMED, Inc, Salt Lake City, UT) electrodes. Positive, reference, and negative electrodes were mounted onto a rigid 2-inch (5.08-cm) bar that also contained a preamplifier. Each electrode was 0.5 inches (1.27 cm) in diameter, spaced 0.375 inches (0.95 cm) apart. The total distance between the center of the positive and the center of the negative electrodes was 1.75 inches (4.45 cm). A very thin plastic washer was placed on each electrode to reduce the conductive area and permit attachment to the skin. The center and outer diameters of the circles of the washer were 0.25 inches (0.64 cm) and 0.75 inches (1.91 cm), respectively.

The rectus abdominis muscle comprises 4 sections separated by 3 tendinous inscriptions. We placed the URA electrode in the middle of the muscle belly in the second section (of 4), inferior to the ribs; the LRA electrode in the muscle belly of the lowest section; the EO electrode directly over the center of that muscle in a diagonal direction, coinciding with the muscle fibers; and the RF electrode on that muscle belly near the proximal end. All electrodes were on the right side of the body with a parallel orientation relative to the muscle fibers (Figure 5).

Data Analysis

The raw EMG signal was sampled at a rate of 1000 Hz, amplified by a factor of 1000, and filtered for electric activity below 20 Hz (high pass) and above 400 Hz (low pass). The data were then rectified and integrated by calculating the area under the rectified curve, providing an indication of the total amount of surface electric activity (iEMG) for the exercise bout. The iEMG for each exercise bout was then divided by the elapsed time for the 5 repetitions to provide the mean

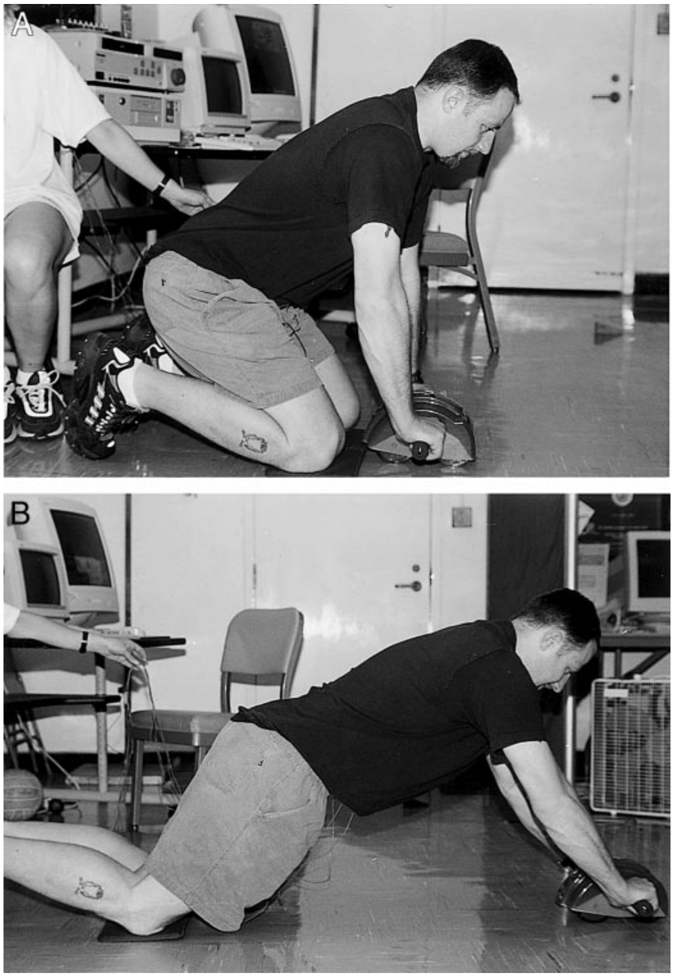

Figure 4. ABslide. A, Start position. B, Top position.

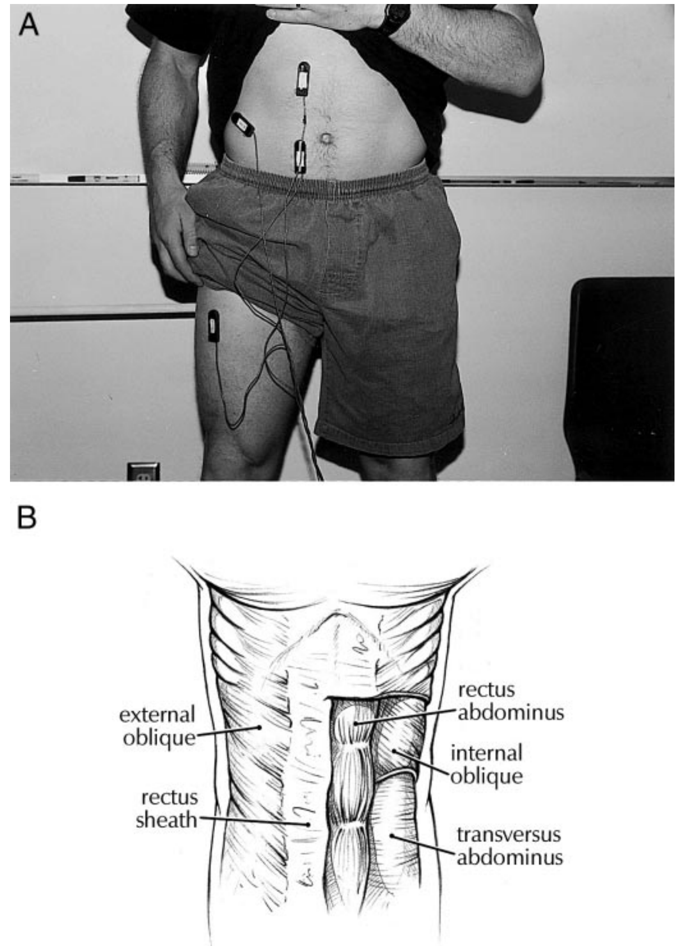

Figure 5. A, Electrode placement. B, Muscle diagram.

iEMG (MiEMG) for each exercise bout, the criterion measure used in the statistical analyses comparing the effects of the different exercise conditions.

We used a repeated-measures, one-way multivariate analysis of variance (MANOVA) to detect differences among the 4 exercise conditions in the MiEMG for the abdominal musculature, combining the URA, LRA, and EO. A repeated-measures, one-way analysis of variance (subject $\times$ order $\times$ exercise) was calculated to detect differences among the 4 exercise conditions for the RF. The analysis of variance also served as a follow-up test for each of the abdominal muscles if the MANOVA statistic was found to be significant. (The model included a test for the effect of order.) We chose the Wilks lambda as the MANOVA criterion statistic. Post hoc tests were performed using the least significant difference method. Although the alpha level was set at 0.05 for all decisions, we report specific probability values associated with each test to provide readers with a more accurate interpretation of the outcomes.

The effect size of the comparisons is also reported to offer an indication of the importance or practical significance of statistically significant comparisons. The effect size was obtained by dividing the mean difference of the comparisons by the pooled standard deviation. Effect sizes of 0.8 or greater are interpreted as large, values in the range of 0.4 to 0.6 are considered moderate, and those below 0.2 are considered small and practically insignificant.[15]

RESULTS

The MiEMG of the abdominal musculature was significantly different across the exercise conditions (Table, Wilks lambda = .3055, $P < .0001$). The MiEMG was significantly different across the exercise conditions for the URA ($P < .0001$), EO ($P < .0001$), and RF ($P < .0009$). However, the alpha level for the LRA was not significant ($P < .051$). Least significant difference post hoc comparisons were run for the URA, LRA, EO, and RF muscles to further evaluate the specific source of significant differences (Figures 6–9). For the URA, the Ab Roller, FitBall, and trunk curl were not significantly different, but these exercises elicited significantly greater activity than did the ABslide (effect size = 1.12). For the LRA, the Ab Roller, FitBall, and trunk curl showed no difference, but the ABslide resulted in significantly less activity than 2 of the other exercise conditions (effect size = 0.67). The EO activity using the ABslide was significantly greater than for the other 3 exercises (effect size = 0.62), whereas exercising with the FitBall and trunk curl produced significantly more activity than the Ab Roller (effect size = 1.24). Comparisons for the RF indicate that the ABslide and FitBall elicited greater activity than the Ab Roller and trunk curl (effect size = 1.12).

DISCUSSION

We chose each exercise device because of the category of equipment it represented and the cost of each device. Exercis-

Total Amount of Surface Electric Activity (iEMG) and Mean iEMG (MiEMG) for Each Exercise Condition and Muscle

Exercise Condition	Muscle	iEMG (mV/s)	Time (s)	MiEMG* (mV)
Trunk curl	Upper rectus abdominis	2016.69 ± 1207.96	9.46	213.43 ± 127.09
	Lower rectus abdominis	1407.77 ± 1005.01	9.46	148.31 ± 104.16
	External oblique	568.23 ± 417.37	9.46	60.69 ± 46.97
	Rectus femoris	87.00 ± 64.83	9.46	9.20 ± 6.91
Ab Roller	Upper rectus abdominis	1822.28 ± 1143.92	9.51	192.23 ± 121.71
	Lower rectus abdominis	1167.04 ± 961.55	9.51	122.18 ± 100.50
	External oblique	356.38 ± 268.26	9.51	37.17 ± 26.96
	Rectus femoris	73.01 ± 43.39	9.51	7.6 ± 4.23
FitBall	Upper rectus abdominis	2186.23 ± 1523.46	9.29	236.78 ± 163.01
	Lower rectus abdominis	1412.89 ± 636.94	9.29	153.4 ± 71.32
	External oblique	550.24 ± 332.45	9.29	60.01 ± 37.72
	Rectus femoris	138.81 ± 77.87	9.29	14.83 ± 7.92
ABslide	Upper rectus abdominis	2957.14 ± 1933.29	20.35	148.1 ± 96.01
	Lower rectus abdominis	1885.56 ± 933.64	20.35	96.21 ± 51.09
	External oblique	1701.77 ± 774.59	20.35	84.38 ± 40.62
	Rectus femoris	338.98 ± 136.94	20.35	17.11 ± 8.00

*Calculated by dividing the iEMG for each trial by the time for each trial.

ing with the ABslide involves different movements (hip, knee, and shoulder flexion and extension) and positions (from hands and knees to prone layout) than any of the other 3 exercise conditions. Also, the ABslide provides resistance during the first movement phase and assistance to the second, return phase. At the time of purchase, it was one of the few devices available that offered this type of resistance. Since the beginning of our study, however, new devices have been developed with this feature and are now available to consumers, yet because the movements involved in using the ABslide are similar in all devices of this type, our results should be representative of their use.

To eliminate and control external variables that may affect muscle activation, we adhered strictly to the manufacturers' guidelines for equipment use. Doing so allowed us to more accurately assess the truthfulness of the efficacy in claims using the abdominal equipment.

We included the RF in our analysis because we proposed activity in this area would be high for exercises in which hip-flexion torque could assist the movement. The ABslide appeared to require the hip joint to flex and extend, and the FitBall required the subject to contract the thigh to maintain proper position on the ball. Greater hip flexion has been shown to diminish the activity of the abdominal muscles and is generally thought to be an undesirable element of safe, effective abdominal exercises. Most previous researchers agree that to increase abdominal activity, the feet should be unsupported, the knees bent, and the hip joint stable.[4,8–10,14–16] The large effect size for this comparison suggests that exercising with both the ABslide and FitBall failed to isolate the abdominal musculature. Exercises on the FitBall likely require the RF to become more involved to maintain the body's position on top of the ball, which does not provide a stable base of support. With the ABslide, the hip joint is in constant motion and also must contract to prevent the upper body from falling to the ground. The difficulty subjects had in performing exercises on the ABslide and FitBall could have also affected the results for these exercise conditions. The subjects had an orientation meeting before testing so they could become familiar with each piece of equipment. This meeting was mandatory, but most subjects claimed prior use of the equipment. Both of these pieces of equipment require a higher level of coordination and familiarization than the other 2 exercise conditions. Subject differences in coordination and familiarization could have led to a greater amount of electric activity among the muscles stabilizing the pelvis, such as the EO and RF.

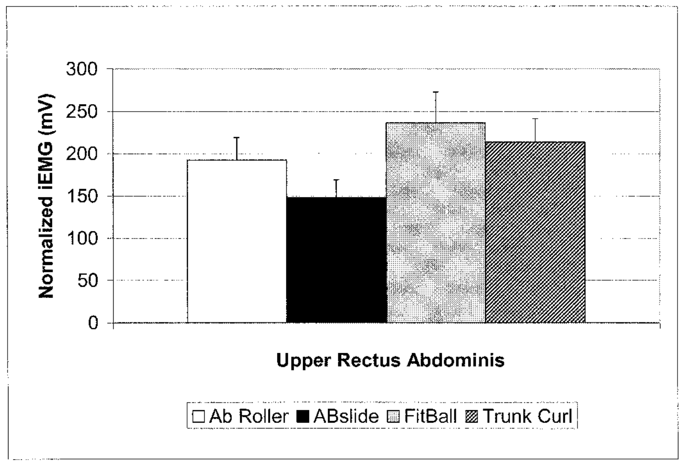

Figure 6. Group mean electric activity for the upper rectus abdominis muscle. The trunk curl, Ab Roller, and FitBall were not different from one another but were different from the ABslide. iEMG indicates surface electric activity.

The finding of an insignificant overall F ratio across exercise conditions for the LRA was surprising. However, because the chance probability of this outcome is only slightly above the critical value, it is possible that methods involving greater statistical power (eg, more subjects, less error) would yield a significant difference. The LRA lies beneath the aponeuroses of the internal and external oblique and transversus abdominis muscles, increasing the potential for cross-talk in the SEMG signals. Cross-talk might have also contributed to the insignificant differences. The moderate to large effect size of this post hoc comparison indicates that the FitBall and trunk curls resulted in a moderate to large effect on the activity of the LRA when compared with exercises using the Ab Roller and ABslide.

The electric activity of the EO while using the ABslide was greater (both statistically and practically) than when exercising

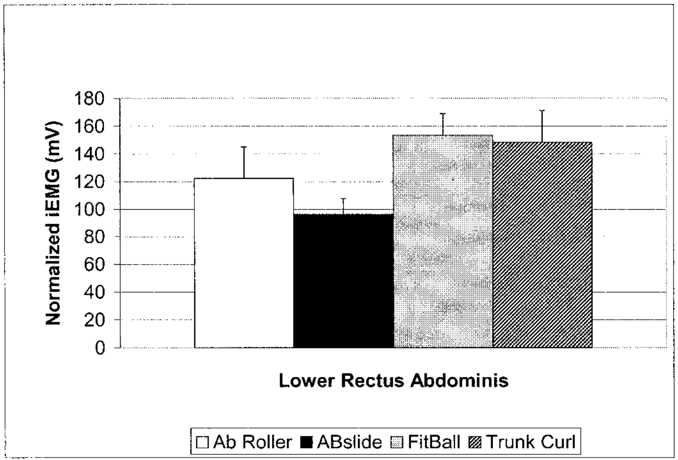

Figure 7. Group mean electric activity for the lower rectus abdominis muscle. The Ab Roller, Fit Ball, and trunk curl were not different from one another but were different from the ABslide. iEMG indicates surface electric activity.

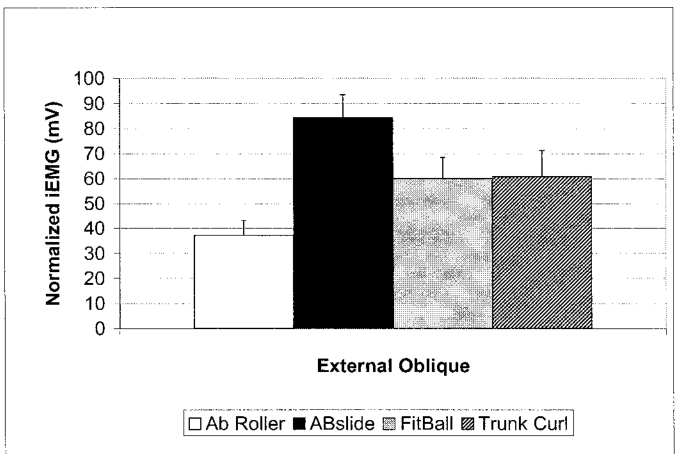

Figure 8. Group mean electric activity for the external oblique muscle. Activity with the ABslide was greater than with the other exercises and the FitBall and trunk curl produced more activity than the Ab Roller. iEMG indicates surface electric activity.

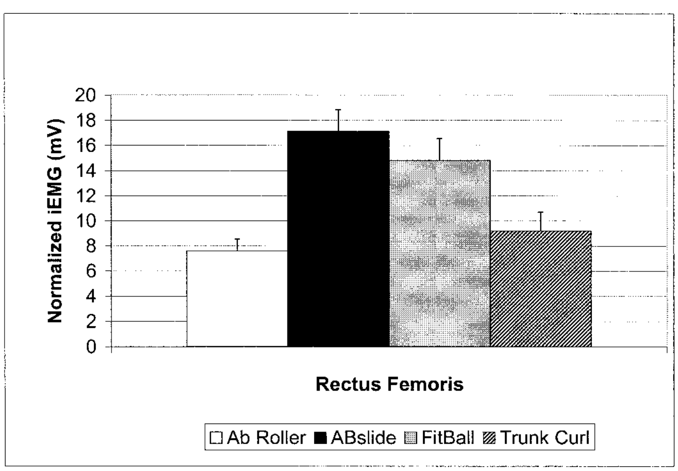

Figure 9. Group mean electric activity for the rectus femoris muscle. The ABslide and FitBall elicited more activity than the Ab Roller and trunk curl. iEMG indicates surface electric activity.

using any of the other modes. This was surprising because its use in this study, although consistent with the ABslide manufacturer's recommendations, did not include modifications designed to isolate the oblique muscles that have been promoted by manufacturers of other devices of this same type. Also, all other exercises examined in this study include manufacturer's instructions on how to isolate the oblique muscles. The FitBall and trunk curl did not significantly differ from each other but were less than the ABslide and greater than the Ab Roller. Because the other exercises can all be modified according to manufacturer's directions to specifically strengthen the EO and the ABslide cannot, this factor may not be an important selection consideration.

We included the EO in our analysis because of the stabilizing role it plays in trunk flexion and its recruitment to assist the rectus abdominis in spinal flexion when greater force is required.[8] The EO's main functions are lateral flexion and rotation, but they are recruited when greater flexion force is required. Noble[9] found that the EO was more consistently affected by different sit-up methods than the URA and LRA. He suggested that this fluctuation in EO activity may be because spinal-flexion movements requiring a greater torque involve the recruitment of the EO. This finding was also supported by significant differences among exercise conditions for the EO.

Warden et al[14] examined the AB Shaper, a device very similar to the Ab Roller we used in terms of the involved movements, and compared it with the traditional trunk curl. We employed procedures similar to theirs regarding electrode positioning, use of a restraining rod, and EMG data acquisition. However, they normalized the iEMG relative to the traditional trunk curl. We did not normalize our EMG data because our data were collected in a single session for within-subjects comparisons only. Also, because we compared 4 exercise conditions, the statistical analysis involved the use of MANOVA and analysis of variance for intergroup comparisons. Normalization results in ratio data and nonnormal distributions that often violate the assumptions associated with these statistical tools. These violations result in inaccurate estimates of the probabilities of observed outcomes relative to chance (ie, alpha). We used MiEMG as the criterion measure, whereas Warden et al[14] used peak and mean EMG values. They reported significantly greater peak and mean EMG values of the URA when using the AB Shaper compared with the traditional trunk curl but no significant differences were found for the LRA and EO. We found no significant difference in MiEMG between the trunk curl and use of the Ab Roller for either the URA or LRA but noted that the use of the Ab Roller involved significantly lower MiEMG of the EO than the trunk curl. These differences in results are likely due to the different data-reduction procedures used in these studies.

Whiting et al[12] compared the electric activity of the URA, LRA, EO, and RF associated with various sit-up methods with and without abdominal exercise devices. The different sit-up methods involved the basic trunk curl in positions and movements similar to those used in our study (arms up, knees flexed to 90°, feet not anchored) as well as other positions and movements. Similar sit-up methods were then employed while using 4 different abdominal exercise devices: Ab Roller Plus (Quantam, Phoenix, AZ), ABSculptor (Tristar Products, Parsippany, NJ), AB Trainer (Precise Exercise, Inc), and AbWorks (NordicTrack, Logan, VT). Three of these devices (Ab Roller Plus, ABSculptor, and AB Trainer) are very similar to the Ab Roller used in our study. Whiting et al[12] used repeated-measures analysis of variance to compare nonnormalized mean EMG data across exercise conditions. Their only significant difference when comparing the devices similar to the Ab Roller Plus with the trunk curl in the arms-up position (similar to the method used in our study) was significantly lower URA activity for the Ab Roller Plus. We found significantly less activity for the Ab Roller Plus than for the trunk curl for the EO and LRA but not significantly different activity for the URA. Neither group found a significant difference between these exercise modes for either the LRA or RF.

The abdominal exercise devices used in this study do not elicit greater electric activity of the URA and LRA than the traditional trunk curl. Also, use of the ABslide elicits greater activity of the EO than all other exercise modes. Both the Ab Roller and trunk-curl exercise involve significantly less activity of the RF, indicative of less hip-flexor contribution to the exercise. Previous researchers[4,8–10,14,17] have discussed the reasons to avoid using the RF when trying to increase abdominal strength and endurance. The powerful hip flexors assist with movement at the hip joint and prevent the traditionally weaker abdominal muscles from working to the fullest. The RF and iliopsoas muscle pull on the pelvis, causing it to tilt forward. This forward tilt leads to increased curvature of the spine, which can result in low back problems and pain.[1,2,18] This undesirable feature of the ABslide and FitBall, as well as the greater orientation and practice time and effort involved in their use, should be considered when making professional decisions regarding their selection in fitness and therapeutic exercise programs.

We conclude that exercising with the different types of abdominal exercise devices available to consumers elicits differences in the electric activity of the abdominal musculature and RF that are both statistically and practically significant. Clinicians and fitness professionals should consider these differences when recommending exercises designed to isolate abdominal muscle activity.

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